

REFLECTANCE SPECTROPHOTOMETRY AND COLORIMETRY- RSC

Introduction

Color has been one of the key factors used for identification of rocks and minerals. The development of handheld spectrophotometers that can quickly produce a detailed spectrum from the surface of a rock or sediment has given scientists a semi-quantitative method of determining composition. The spectrophotometer allowed higher density, non-invasive analyses which could identify changes in composition, cyclical changes, and could help pinpoint where the beginning of the changes occurred. These types of data helped with core to core and hole to hole correlations. Some sediment constituents have characteristic spectral signatures that could be used to better estimate the quantity of those constituents in sediments before samples were taken for detailed analysis.

The Ocean Drilling Program (ODP) began using the Minolta photospectrometer CM-2002 on Leg 154. The Minolta measured the reflected light from the surface of the core over the visible spectrum (400 - 700 nm). Over 2,250,000 RSC measurements were taken with the Minolta during the 39 legs in which color reflectance data were taken.

Data Acquisition

The Minolta CM-2002 spectrophotometer was used to collect color reflectance (RSC) data during the ODP. For the first few years, the Minolta was operated manually. This required a significant effort on the part of the scientists and laboratory technicians to collect these data. The measurement of RSC was time-critical because of the changes that occurred in the surface of the split core as the sediment or rock was exposed to air. During Leg 180, the Minolta was mounted on the AMST (Archive MultiSensor Track) in order to automate data acquisition. There were some problems with track operation and the automated data acquisition for a few legs, but starting on Leg 188, RSC data were routinely collected with the track system rather than manually.

Standard Operating Procedures

RSC measurements were taken on the archive half, preferably about 1 hour after the core had been split. The split core was covered with GLAD Cling Wrap to protect the glass cover on the aperture of the Minolta since the instrument was set on the surface when taking measurements. [The GLAD Cling Wrap transmits light uniformly over the spectrum of visible light and has minimal effect on the spectra (Blum, 1997)]. Even under manual operation, the data were acquired with PC-based data acquisition software.

The Minolta had several options that affected the measurement and processing of reflectance data. The recommended settings for ODP cores were:

- SCE setting – specular component excluded – option to include or exclude a glare component of the reflected light. The glare component did not contribute to the spectrum.
- D65 illuminant – represents average daylight throughout the visible spectrum.
- 10° standard observer or 10° field of view.
- Output color parameters X, Y, Z, L*, a*, b* and Munsell HVC notation.

In addition to the spectral measurements downloaded from the Minolta, the camera's acquisition program also calculated standard color parameters. The Munsell HVC (hue, value and chroma) color system had been used by Earth scientists for many years as a way to standardize color descriptions of rocks. However, new color systems have been developed recently that relate reflectance spectra to color. The tristimulus system is based on matching a color under standardized conditions against the three primary colors - red, green and blue, which are expressed as values X, Y, and Z. The tristimulus values can also be related to spectral wavelength. The L*a*b* color space system was recommended for sediment and rock analyses. In the L*a*b* system, L* is the lightness variable, a* and b* are chromaticity variables - a* is the green to red axis and b* is the blue to yellow axis.

Calibration

Two types of calibration were performed on the Minolta CM-2002. A *zero calibration* was performed by aiming the aperture into a space where there were no objects within 1 meter and no light source aimed at it. This calibration was performed to compensate for effects of stray light due to the flare characteristics of the optical system. A *white calibration* was performed immediately after a zero calibration. The standard was a white ceramic cap supplied with the Minolta CM-2002 that was factory-calibrated over the 400 nm to 700 nm range. White calibrations were performed regularly. After the Janus database was operational, white calibration data were archived in the database.

Archive

Pre-Janus Archive

The original RSC data files were archived in the ODP/TAMU servers. There was no interim database for RSC data. The reflectance spectra were stored in the camera and downloaded to a file using a PC-base data acquisition program. The convention was to create a file after all the sections of a core were analyzed.

Migration of RSC Data to Janus

The data model for RSC can be found in Appendix I. Included are the relational diagram and the list of the tables that contain data pertinent to RSC, the column names, and the definition of each column attribute. ODP Information Services Database Group was responsible for the migration of pre-Leg 171 data to Janus. In order to ensure that the X, Y, Z, L*, a*, and b* parameters were calculated based on the D65 illuminant and 10° standard observer, these parameters were recalculated and uploaded for the migrated data.

Janus RSC Color Reflectance Data Format

Color reflectance data are available through the Janus web query Color Reflectance. The RSC query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, depth ranges, or latitude and longitude ranges. In addition, the user can use the Output Raw Data option in the query to extract the the spectral reflectance percentages for each wavelength. Additional information about ODP Color Reflectance data can be found in *Technical Note 26: Physical Properties Handbook*, Chapter 7.

Table 1. Color Reflectance query with Output Raw Data option

Item Name	Janus Table	Janus Column Name and Calculation
Leg	SECTION	leg
Site	SECTION	site
Hole	SECTION	hole
Core	SECTION	core
Type	SECTION	core_type
Section	SECTION	section_number
Top (cm)	RSC_RUN_DATA	top_interval X 100.
Depth (mbst)	RSC_RUN_DATA	Depth_map.map_top_interval + rsc_run_data.top_interval
Run Number	RSC_RUN	rsc_run_num
Num Meas	RSC_RUN	rsc_num_meas
Run Date/Time	RSC_RUN	rsc_run_date_time
CIELAB L*	RSC_RUN_DATA	rsc_cielab_l_star
CIELAB a*	RSC_RUN_DATA	rsc_cielab_a_star
CIELAB b*	RSC_RUN_DATA	rsc_cielab_b_star
Height	RSC_RUN_DATA	rsc_height
Height Flag	RSC_RUN_DATA	rsc_height_assumed_flag
Munsell_HVC	RSC_RUN_DATA	rsc_munsell_hvc
Tristimulus_X	RSC_RUN_DATA	rsc_tristimulus_x
Tristimulus_Y	RSC_RUN_DATA	rsc_tristimulus_y
Tristimulus_Z	RSC_RUN_DATA	rsc_tristimulus_z
First Channel Wavelength	RSC_RUN_DATA	rsc_first_channel
Last Channel Wavelength	RSC_RUN_DATA	rsc_last_channel
Wavelength Increment	RSC_RUN_DATA	rsc_increment
400 (nm)	RSC_RUN_DATA	rsc_spectra
410 (nm)	RSC_RUN_DATA	rsc_spectra
420 (nm)	RSC_RUN_DATA	rsc_spectra
430 (nm)	RSC_RUN_DATA	rsc_spectra
440 (nm)	RSC_RUN_DATA	rsc_spectra
450 (nm)	RSC_RUN_DATA	rsc_spectra

Item Name	Janus Table	Janus Column Name and Calculation
460 (nm)	RSC_RUN_DATA	rsc_spectra
470 (nm)	RSC_RUN_DATA	rsc_spectra
480 (nm)	RSC_RUN_DATA	rsc_spectra
490 (nm)	RSC_RUN_DATA	rsc_spectra
500 (nm)	RSC_RUN_DATA	rsc_spectra
510 (nm)	RSC_RUN_DATA	rsc_spectra
520 (nm)	RSC_RUN_DATA	rsc_spectra
530 (nm)	RSC_RUN_DATA	rsc_spectra
540 (nm)	RSC_RUN_DATA	rsc_spectra
550 (nm)	RSC_RUN_DATA	rsc_spectra
560 (nm)	RSC_RUN_DATA	rsc_spectra
570 (nm)	RSC_RUN_DATA	rsc_spectra
580 (nm)	RSC_RUN_DATA	rsc_spectra
590 (nm)	RSC_RUN_DATA	rsc_spectra
600 (nm)	RSC_RUN_DATA	rsc_spectra
610 (nm)	RSC_RUN_DATA	rsc_spectra
620 (nm)	RSC_RUN_DATA	rsc_spectra
630 (nm)	RSC_RUN_DATA	rsc_spectra
640 (nm)	RSC_RUN_DATA	rsc_spectra
650 (nm)	RSC_RUN_DATA	rsc_spectra
660 (nm)	RSC_RUN_DATA	rsc_spectra
670 (nm)	RSC_RUN_DATA	rsc_spectra
680 (nm)	RSC_RUN_DATA	rsc_spectra
690 (nm)	RSC_RUN_DATA	rsc_spectra
700 (nm)	RSC_RUN_DATA	rsc_spectra

Data Quality

There are several things that affect the quality of RSC data. The type of material and the drilling method used to recover the core are major factors. Disturbed material, with cracks and voids would yield poor quality measurements. Factors such as surface moisture or uncontrolled drying of the material, surface roughness, particle size, oxidation and use of the protective plastic wrap could also affect the quality of the data.

Data quality was also dependent on the operator. The Minolta was manually operated for several legs. The operator needed to be sure the camera was properly set up and calibrated, placed on the core surface properly and held in contact with the surface for the required period of time for each measurement. Even a tiny crack that allowed ambient light inside could contaminate the measurement.

There were problems when the Minolta was to be mounted on the AMST. It was thought that the aperture could be held slightly about the split-core surface to take measurements with the data corrected by a height adjustment. This would have been beneficial for at least two reasons: the section would not have to be wrapped in plastic wrap, and movement of the camera down the track would be somewhat easier. However, data collected in this configuration were very poor. Light contamination made the spectra essentially useless. Data were collected on legs 180 - 183, 185 and 186 before the problems were corrected. These data were not entered into the database but can be requested through the IODP Data Librarian. The Shipboard Scientific Parties for those legs indicated that the spectral data may be okay in a relative sense,

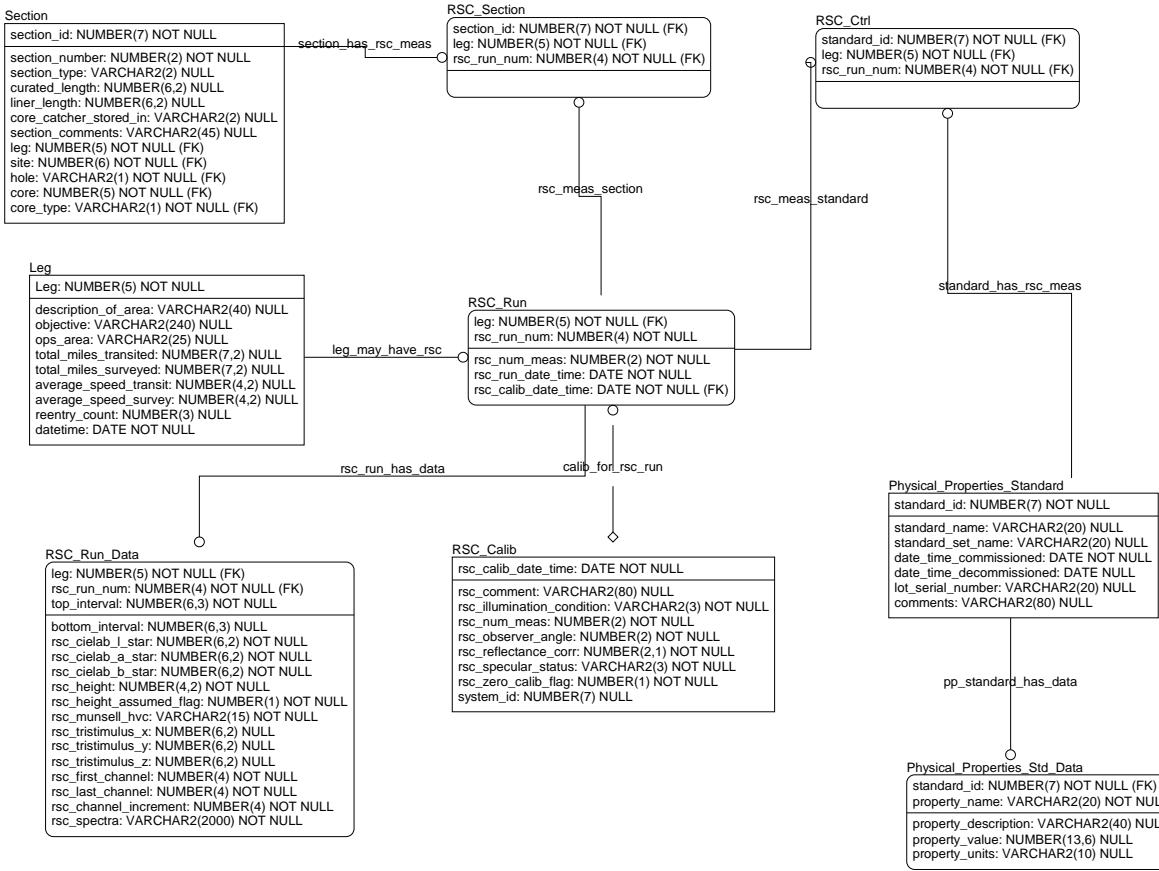
but the absolute spectral values are damaged. (Data collected on Leg 184 and Leg 186 were done by the older manual method.)

After the track-mounted system was operational, there could still be operator errors. Throughout the ODP, the operator manually entered core information into the data acquisition program. Typographical errors or entering the wrong section identification information occasionally happened, and some mistakes were not identified. An effort was made during the verification of post-Leg 171 data to find sections that were misidentified. This was done using logsheets that were often used to document the analyses on AMST, and looking for clues to misidentified analyses. Some of the clues that were used to find misidentified sections include:

- two runs for a section, but no run for the following section;
- run numbers out of sequence;
- two runs for a section, run numbers out of sequence, but no data for that core number and section in a different hole. Run number sequence would be correct if placed in different hole.
- Comparison of data, and nature of the core material – length of core, voids, etc.

Reference

Blum, P., 1997, Physical Properties Handbook: A guide to the shipboard measurement of physical properties of deep-sea cores, ODP Tech. Note 26.



Appendix I. Janus Data Model – Color Reflectance (RSC)

Color Reflectance - RSC		
Table Name	Column Name	Column Comment
RSC_Section	section_id	Unique Oracle-generated sequence number to identify each section.
	leg	Number identifying the cruise for which data were entered into the database.
	rsc_run_num	Number identifying a run generated by the data acquisition software.
RSC_Run	leg	Number identifying the cruise for which data were entered into the database.
	rsc_run_num	Number identifying a run generated by the data acquisition software.
	rsc_num_meas	Number of measurements included in the average. Usually multiple measurements are taken at each position, and these measurements are averaged.
	rsc_run_date_time	Timestamp when analysis was run.
	rsc_calib_date_time	Timestamp when calibration was run.
RSC_Run_Data	leg	Number identifying the cruise for which data were entered into the database.
	rsc_run_num	Number identifying a run generated by the data acquisition software.
	top_interval	The top interval of a measurement in meters measured from the top of a section.
	bottom_interval	The bottom interval of a measurement in meters measured from the top of a section.
	rsc_cielab_l_star	The Lightness variable in the CIELAB system color notation, ranging from 0% - 100% (method based on CIE COLORIMETRY, Second edition, Publication 15.2 (1986)).
	rsc_cielab_a_star	A chromaticity coordinate in the CIELAB system color notation, ranging from green to red.
	rsc_cielab_b_star	A chromaticity coordinate in the CIELAB system color notation, ranging from blue to yellow.
	rsc_height	Distance between surface of material and spectrophotometer aperture (in millimeters).
	rsc_height_assumed_flag	0 or 1 to perform height correction.
	rsc_munsell_hvc	Munsell HVC color notation – hue, value, chroma (ASTM D 1525-1980, Standard Method of Specifying Color by the Munsell System).
	rsc_tristimulus_x	Primary value in the CIE system. Equal values of X, Y, and Z produce white.
	rsc_tristimulus_y	Primary value in the CIE system. Equal values of X, Y, and Z produce white.
	rsc_tristimulus_z	Primary value in the CIE system. Equal values of X, Y, and Z produce white.
	rsc_first_channel	Wavelength of first channel measured for a color reflectance measurement, in nanometers.
	rsc_last_channel	Wavelength of last channel measured for a color reflectance measurement, in nanometers.
	rsc_channel_increment	The increment between measured wavelengths for a color reflectance measurement, in nanometers.
	rsc_spectra	The spectral results for a color reflectance measurement. Data stored in a single comma or space delimited string.
RSC_Calib	rsc_calib_date_time	Timestamp when calibration was run.
	rsc_comment	Comment concerning calibration run.
	rsc_illumination_condition	Predefined conditions of the measurement such as A, C, D50 or D65.
	rsc_num_meas	Number of measurements included in the average. Usually multiple measurements are taken at each position, and these measurements are averaged.
	rsc_observer_angle	The angle of illumination at which the specimen is observed, in degrees.
	rsc_reflectance_corr	Correction used to calculate data for the specular component excluded (SCE) data from the specular component included (SCI) data.
	rsc_specular_status	Identifies Specular component status. Valid values: SCE - specular component excluded or SCI - specular component included.
	rsc_zero_calib_flag	Indicator that zero calibrated (=1).

Color Reflectance - RSC

Table Name	Column Name	Column Comment
	system_id	Unique identifier for a system of equipment on the ship.

RSC_Ctrl	standard_id	Unique identifier for a physical properties standard.
	leg	Number identifying the cruise for which data were entered into the database.
	rsc_run_num	Number identifying a run generated by the data acquisition software.

Physical_Properties_Standard	standard_id	Unique identifier for a physical properties standard.
	standard_name	Name of a physical properties standard.
	standard_set_name	The name for a set of physical properties standards.
	date_time_commissioned	The date that a physical properties standard went into use.
	date_time_decommissioned	The date that a physical properties standard's use was discontinued.
	lot_serial_number	Information concerning the lot and/or serial number associated with a physical properties standard.
	Comments	General comments.

Physical_Properties_Std_Data	standard_id	Unique identifier for a physical properties standard.
	property_name	A property associated with a physical properties standard, for example material or density.
	property_description	Description of the property associated with a physical properties standard.
	property_value	Value of a property associated with a physical properties standard.
	property_units	Units associated with a property for a physical properties standard.

Section	section_id	Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber.
	leg	Number identifying the cruise for which data were entered into the database.
	site	Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.
	hole	Letter identifying the hole at a site from which a core was retrieved or data were collected.
	core	Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.
	core_type	A letter code identifying the drill bit/coring method used to retrieve the core.
	section_number	Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.
	section_type	Used to differentiate sections of core (S) from core catchers (C). Previously core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.
	curated_length	The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.
	liner_length	The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.
	core_catcher_stored_in	Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.
	section_comments	Comments about this section

Leg	Leg	Number identifying the cruise for which data were entered into the database.
	description_of_area	General description of the area where the sites are located.
	objective	General objectives and accomplishments of leg.
	ops_area	Operating area for leg.

Color Reflectance - RSC

Table Name	Column Name	Column Comment
	total_miles_transited	Total miles transited during leg.
	total_miles_surveyed	Total miles surveyed during leg
	average_speed_transit	Average transit speed for cruise
	average_speed_survey	Average speed during surveys done on leg
	reentry_count	Number of hole reentries performed during Leg
	datetime	Generic date/time.

Appendix II: Description of data items from RSC query.

Column Name	Column Description	Format
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the <i>JR</i> at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the <i>JR</i> .	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The <i>JR</i> visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. GRA measurements were made on sections. Core Catcher sections identified as "CC".	Integer 2 (Text 2)
Top (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the measurement location.	Decimal F7.3
Run Number	Number generated by the data acquisition software, to identify an analysis run of a section of core.	Integer 4
Num Meas	Number of measurements included in the average.	Integer 1
Run Date/Time	Timestamp when analysis was run.	Text 16 (yyyy-mm-dd hh:mi)
CIELAB_L*	The Lightness variable in the CIELAB system color notation, ranging from 0% - 100%.	Decimal F6.2
CIELAB_a*	A chromaticity coordinate in the CIELAB system color notation, ranging from green to red.	Decimal F6.2
CIELAB_b*	A chromaticity coordinate in the CIELAB system color notation, ranging from blue to yellow.	Decimal F6.2
Height	Distance between surface of material and spectrophotometer aperture (in millimeters).	Decimal F4.2
Height Flag	Distance between surface of material and spectrophotometer aperture (in millimeters).	Integer 1

Column Name	Column Description	Format
Munsell_HVC	Munsell HVC color notation – hue, value, chroma (ASTM D 1525-1980, Standard Method of Specifying Color by the Munsell System).	Text 15
Tristimulus_X	Primary value in the CIE system. Equal values of X, Y, and Z produce white.	Decimal F6.2
Tristimulus_Y	Primary value in the CIE system. Equal values of X, Y, and Z produce white.	Decimal F6.2
Tristimulus_Z	Primary value in the CIE system. Equal values of X, Y, and Z produce white.	Decimal F6.2
First Channel Wavelength	Wavelength of first channel measured for color reflectance, in nanometers.	Integer 4
Last Channel Wavelength	Wavelength of last channel measured for color reflectance, in nanometers.	Integer 4
Wavelength Increment	Increment in nanometers between measured wavelengths.	Integer 4
400 (nm)	Reflectance value at 400 nm in % intensity	Decimal F5.2
410 (nm)	Reflectance value at 410 nm in % intensity	Decimal F5.2
420 (nm)	Reflectance value at 420 nm in % intensity	Decimal F5.2
430 (nm)	Reflectance value at 430 nm in % intensity	Decimal F5.2
440 (nm)	Reflectance value at 440 nm in % intensity	Decimal F5.2
450 (nm)	Reflectance value at 450 nm in % intensity	Decimal F5.2
460 (nm)	Reflectance value at 460 nm in % intensity	Decimal F5.2
470 (nm)	Reflectance value at 470 nm in % intensity	Decimal F5.2
480 (nm)	Reflectance value at 480 nm in % intensity	Decimal F5.2
490 (nm)	Reflectance value at 490 nm in % intensity	Decimal F5.2
500 (nm)	Reflectance value at 500 nm in % intensity	Decimal F5.2
510 (nm)	Reflectance value at 510 nm in % intensity	Decimal F5.2
520 (nm)	Reflectance value at 520 nm in % intensity	Decimal F5.2
530 (nm)	Reflectance value at 530 nm in % intensity	Decimal F5.2
540 (nm)	Reflectance value at 540 nm in % intensity	Decimal F5.2
550 (nm)	Reflectance value at 550 nm in % intensity	Decimal F5.2
560 (nm)	Reflectance value at 560 nm in % intensity	Decimal F5.2
570 (nm)	Reflectance value at 570 nm in % intensity	Decimal F5.2
580 (nm)	Reflectance value at 580 nm in % intensity	Decimal F5.2
590 (nm)	Reflectance value at 590 nm in % intensity	Decimal F5.2
600 (nm)	Reflectance value at 600 nm in % intensity	Decimal F5.2
610 (nm)	Reflectance value at 610 nm in % intensity	Decimal F5.2
620 (nm)	Reflectance value at 620 nm in % intensity	Decimal F5.2
630 (nm)	Reflectance value at 630 nm in % intensity	Decimal F5.2
640 (nm)	Reflectance value at 640 nm in % intensity	Decimal F5.2
650 (nm)	Reflectance value at 650 nm in % intensity	Decimal F5.2
660 (nm)	Reflectance value at 660 nm in % intensity	Decimal F5.2
670 (nm)	Reflectance value at 670 nm in % intensity	Decimal F5.2
680 (nm)	Reflectance value at 680 nm in % intensity	Decimal F5.2
690 (nm)	Reflectance value at 690 nm in % intensity	Decimal F5.2
700 (nm)	Reflectance value at 700 nm in % intensity	Decimal F5.2